SECTION 15950
TESTING, ADJUSTING, AND BALANCING

PART 1 - GENERAL

1.01 PROVISIONS INCLUDED

A. The general provisions of the Contract, including General and Supplementary Conditions, and Division 1 General Requirements, apply to work specified in this Section.

B. Requirements of Section 15050, "Basic Mechanical Materials and Methods" apply to work specified in this Section.

1.02 SUMMARY

A. This Section includes testing, adjusting, and balancing HVAC systems to produce design objectives, including the following:
   1. Balancing water flow within distribution systems, including submains, branches, and terminals, to indicated quantities according to specified tolerances.
   2. Balancing air flow within the existing Science Wing.
   3. Measuring electrical performance of HVAC equipment.
   4. Setting quantitative performance of HVAC equipment.
   5. Verifying that automatic control devices are functioning properly.
   6. Reporting results of the activities and procedures specified in this Section.

B. Test, adjust and balance the hydronic system.
   1. The basic hydronic system is existing including pumps, heat exchangers and controls. This project extends the existing system to provide heating hot water to new and relocated terminal devices.
   2. Test and balance the extended distribution system.
   3. Verify existing heat exchanger and pump performance before construction and after new installation is complete.

C. Test, adjust and balance the Science Wing exhaust system.
   1. The Science Wing general exhaust system is existing and connected to the Biosciences Wing energy recovery system. The project removes the connection to the Biosciences Wing and extends the general exhaust to a new general exhaust fan.
   2. Test and balance the extended Science Wing general exhaust system.
   3. Verify the Science Wing general exhaust before construction and after new installation is complete.
   4. Verify performance of the existing energy recovery exhaust system after new installation is complete, optimizing performance with two exhaust fans running.

D. Test, adjust and balance the Science Wing supply system.

1. The Science Wing general supply system is existing. The project modifies the outside air connection to AH-2, disables inlet vanes on the supply fan, locking them in a full open position and adds a veriable speed drive to the supply fan.
2. Test and balance the modified unit and supply distribution through the Science Wing.
3. Verify supply before construction and after new installation is complete.

E. Verify temperature control system operation.

1.03 DEFINITIONS AND ABBREVIATIONS

A. Adjust: To regulate fluid flow rate and air patterns at the terminal equipment, such as to reduce fan speed or adjust a damper.

B. Balance: To proportion flows within the distribution system, including submains, branches, and terminals, according to design quantities.

C. Draft: A current of air, when referring to localized effect caused by one or more factors of high air velocity, low ambient temperature, or direction of airflow, whereby more heat is withdrawn from a person's skin than is normally dissipated.

D. Procedure: An approach to and execution of a sequence of work operations to yield repeatable results.

E. Report Forms: Test data sheets for recording test data in logical order.

F. Static Head: The pressure due to the weight of the fluid above the point of measurement. In a closed system, static head is equal on both sides of the pump.

G. Suction Head: The height of fluid surface above the centerline of the pump on the suction side.

H. System Effect: A phenomenon that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system.

I. System Effect Factors: Allowances used to calculate a reduction of the performance ratings of a fan when installed under conditions different from those presented when the fan was performance tested.

J. Terminal: A point where the controlled medium, such as fluid or energy, enters or leaves the distribution system.

K. Test: A procedure to determine quantitative performance of a system or equipment.

L. Testing, Adjusting, and Balancing Agent: The entity responsible for performing and reporting the testing, adjusting, and balancing procedures.

M. AABC: Associated Air Balance Council.

N. AMCA: Air Movement and Control Association.

O. NEBB: National Environmental Balancing Bureau.

P. SMACNA: Sheet Metal and Air Conditioning Contractors' National Association.

1.04 SUBMITTALS

A. Provide

B. Quality-Assurance Submittals: Submit 2 copies of evidence that testing, adjusting, and balancing Agent and this Project's testing, adjusting, and balancing team members meet the qualifications specified in the "Quality Assurance" Article below with the General Contractor's initial application for payment, as specified in Section 01290, "Payment Procedures",.

C. Contract Documents Examination Report: Submit 2 copies of Contract Documents examination report as specified in Part 3 of this Section within 45 days from the Contractor's Notice to Proceed.

D. Strategies and Procedures Plan: Submit 2 copies of the testing, adjusting, and balancing strategies and step-by-step procedures as specified in Part 3 "Preparation" Article below within 60 days from the Contractor's Notice to Proceed. Include a complete set of report forms intended for use on this Project.

E. Certified Testing, Adjusting, and Balancing Reports: Submit 2 copies of reports prepared, as specified in this Section, on approved forms certified by the testing, adjusting, and balancing Agent.

E. Warranty: Submit 2 copies of special warranty specified in the "Warranty" Article below.

1.05 QUALITY ASSURANCE

A. Agent Qualifications: Engage a testing, adjusting, and balancing agent certified by either AABC or NEBB.

B. Testing, Adjusting, and Balancing Conference: Meet with Owner's and Architect's representatives on approval of testing, adjusting, and balancing strategies and procedures plan to develop a mutual understanding of the details. Ensure participation of testing, adjusting, and balancing team members, HVAC controls Installer, and other support personnel. Provide 7 days advance notice of scheduled meeting time and location.
   1. Agenda Items: Include at least the following:
      a. Submittal distribution requirements.
      b. Contract Documents examination report.
      c. Testing, adjusting, and balancing plan.
      d. Work schedule and Project site access requirements.
      f. Coordination and cooperation of trades and subcontractors.
      g. Coordination of documentation and communication flow.

C. Certification of Testing, Adjusting, and Balancing Reports: Certify the testing, adjusting, and balancing field data reports. This certification includes the following:

1. Review field data reports to validate accuracy of data and to prepare certified testing, adjusting, and balancing reports.
2. Certify that testing, adjusting, and balancing team complied with approved testing, adjusting, and balancing plan and procedures specified and referenced in this Specification.

D. Testing, Adjusting and Balancing Reports: Use standard forms from AABC's "National Standards for Testing, Adjusting, and Balancing", or from NEBB's "Procedural Standards for Testing, Adjusting and Balancing of Environmental Systems".

E. Instrumentation Calibration: Calibrate instruments at least every 6 months or more frequently if required by instrument manufacturer.

1.06 PROJECT CONDITIONS

A. Systems Operation: Systems shall be fully operational prior to beginning procedures.

B. Owner Occupancy: The Science Wing is fully occupied as well as areas in the Biosciences Wing served by the hydronic system and energy recovery exhaust system. Cooperate with Owner during testing, adjusting, and balancing operations to minimize conflicts with Owner's operations.

1.07 COORDINATION

A. Coordinate efforts of factory-authorized service representatives for systems and equipment, HVAC controls installers, and other mechanics to operate HVAC systems and equipment to support and assist testing, adjusting, and balancing activities.

B. Notice: Provide 7 days' advance notice for each test. Include scheduled test dates and times.

C. Perform testing, adjusting, and balancing after leakage and pressure tests on air and water distribution systems have been satisfactorily completed.

1.08 WARRANTY

A. Provide a guarantee on AABC'S "National Standards" forms, or on NEBB forms, stating that AABC or NEBB, respectively, will assist in completing the requirements of the Contract Documents if the testing, adjusting, and balancing Agent fails to comply with Contract Documents. Guarantee includes the following provisions:
1. The certified Agent has tested and balanced systems according to the Contract Documents.
2. Systems are balanced to optimum performance capabilities within design and installation limits.

PART 2 - PRODUCTS

(NOT USED)

PART 3 - EXECUTION

3.01 EXAMINATION

A. Examine Contract Documents to become familiar with project requirements and to discover conditions in system designs that may preclude proper testing, adjusting, and balancing of systems and equipment.
   1. Contract Documents are defined in the General Conditions of the Contract.
   2. Verify balancing devices, such as test ports, gage cocks, thermometer wells, flow-control devices, balancing valves and fittings, and manual volume dampers, are required by Contract Documents. Verify quantities and locations of balancing devices are accessible and appropriate for effective balancing and for efficient system and equipment operation.

B. Examine approved submittal data of HVAC systems and equipment.

C. Examine project record documents described in Section 01770, "Closeout Submittals."

D. Examine equipment performance data, including fan and pump curves. Relate performance data to project conditions and requirements, including system effects that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system. Calculate system effect factors to reduce performance ratings of HVAC equipment when installed under conditions different from those presented when equipment was performance tested at factory. To calculate system effects for air systems, use tables and charts found in AMCA 201, "Fans and Systems," Sections 7 through 10; or in SMACNA's "HVAC Systems--Duct Design," Sections 5 and 6. Compare this data with design data and installed conditions.

E. Examine system and equipment installations to verify they are complete and that testing, cleaning, adjusting, and start-up specified in individual Specification Sections have been performed.

F. Examine system and equipment test reports.

G. Examine HVAC system and equipment installations to verify indicated balancing devices, such as test ports, gage cocks, thermometer wells, flow-control devices, balancing valves and fittings, and manual volume dampers, are properly installed, and their locations are accessible and appropriate for effective balancing and for efficient system and equipment operation.

H. Examine systems for functional deficiencies that cannot be corrected by adjusting and balancing.

I. Examine strainers for clean screens and proper perforations.

J. Examine automatic temperature control system components to verify the following:
   1. Dampers, valves, and other controlled devices operate by intended controller.
   2. Dampers and valves are in position indicated by controller.
   3. Integrity of valves and dampers for free and full operation and for tightness of fully closed and fully open positions.
   4. Sensors are located to sense only the intended conditions.

5. Sequence of operation for control modes is according to the Contract Documents.
6. Controller set points are set at design values. Observe and record system reactions to changes in conditions. Record default set points if different from design values.

K. Report deficiencies discovered before and during performance of testing, adjusting, and balancing procedures.

3.02 PREPARATION

A. Prepare a testing, adjusting, and balancing plan that includes strategies and step-by-step procedures.

B. Complete system readiness checks and prepare system readiness reports. Verify the following:
1. Permanent electrical power wiring is complete.
2. Hydronic systems are filled, clean, and free of air.
3. Automatic temperature-control systems are operational.
4. Isolating and balancing valves are open and control valves are operational.

3.03 GENERAL TESTING AND BALANCING PROCEDURES

A. Perform testing and balancing procedures on each system according to the procedures contained in AABC national standards, or in NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems" and this Section.

B. Cut insulation, ducts, pipes, and equipment cabinets for installation of test probes to minimum extent necessary to allow adequate performance of procedures. After testing and balancing, close probe holes and patch insulation with new materials identical to those removed. Restore vapor barrier and finish according to insulation Specifications for this Project. Securly install plugs in test ports

C. Mark equipment settings with paint or other suitable, permanent identification material, including damper-control positions, valve indicators, fan-speed-control levers, and similar controls and devices, to show final settings.

3.04 FUNDAMENTAL PROCEDURES FOR HYDRONIC SYSTEMS

A. Prepare test reports with pertinent design data and number in sequence starting at pump to end of system. Check sum of branch-circuit flows against approved pump flow rate. Correct variations that exceed plus or minus 5 percent.

B. Prepare schematic diagrams of system "as-built" piping layouts.

C. Prepare hydronic systems for testing and balancing according to the following, in addition to general preparation procedures specified above:
1. Open all manual valves for maximum flow.
2. Check expansion tank liquid level.
3. Check makeup-water-station pressure gage for adequate pressure for highest vent.
4. Check flow-control valves for specified sequence of operation and set at design flow.

5. Set differential-pressure control valves at specified differential pressure. Do not set at fully closed position when pump is positive-displacement type, unless several terminal valves are kept open.
6. Set system controls so automatic valves are wide open to heat exchangers.
7. Check pump-motor load. If motor is overloaded, throttle main flow-balancing device so motor nameplate rating is not exceeded.
8. Check air vents for a forceful liquid flow exiting from vents when manually operated.

3.05 HYDRONIC SYSTEM BALANCING PROCEDURES

A. Determine water flow at pumps. The heating hot water pumps are existing. Use the following procedures to verify performance prior to extension of the heating hot water system and again after the system extension is complete:

1. Verify impeller size by operating pump with discharge valve closed. Verify with pump manufacturer this will not damage pump. Read pressure differential across pump. Convert pressure to head and correct for differences in gage heights. Note point on the manufacturer's pump curve at zero flow and confirm pump has intended impeller size.

2. Check system resistance. With all valves open, read pressure differential across pump and mark pump manufacturer's head-capacity curve. Adjust pump discharge valve until design water flow is achieved.

3. Verify pump-motor brake horsepower. Calculate intended brake horsepower for system based on pump manufacturer's performance data. Compare calculated brake horsepower with nameplate data on pump motor. Report conditions where actual amperage exceeds motor nameplate amperage.

4. Report flow rates that are not within plus or minus 5 percent of design.

B. Set calibrated balancing valves, if installed, at calculated presettings.

C. Measure flow at all stations and adjust, where necessary, to obtain first balance.

1. System components that have Cv rating or an accurately cataloged flow-pressure-drop relationship may be used as a flow-indicating device.

D. Measure flow at main balancing station and set main balancing device to achieve flow that is 5 percent greater than design flow.

E. Adjust balancing stations to within specified tolerances of design flow rate as follows:
1. Determine balancing station with highest percentage over design flow.
2. Adjust each station in turn, beginning with station with highest percentage over design flow and proceeding to the station with the lowest percentage over design flow.
3. Record settings and mark balancing devices.

F. Measure pump flow rate and make final measurements of pump amperage, voltage, rpm, pump heads, and system pressures and temperatures, including outdoor-air temperature.

G. Measure differential-pressure control valve settings existing at conclusions of balancing.

3.06 HEAT EXCHANGERS

A. The steam to hot water heat exchangers are existing. Use the following procedures to verify performance prior to extension of the heating hot water system and again after the system extension is complete:

1. Measure water flow through all circuits.
2. Adjust water flow to within specified tolerances.
3. Measure inlet and outlet water temperatures.
4. Measure inlet steam pressure. Check setting and operation of automatic temperature-control valves, self-contained control valves, and pressure-reducing valves.
5. Record safety valve settings.
6. Verify operation of steam traps.

3.07 MOTORS

A. Motors, 1/2 HP and Larger: Test at final balanced conditions and record the following data:
1. Manufacturer, model, and serial numbers.
2. Motor horsepower rating.
3. Motor rpm.
4. Efficiency rating if high-efficiency motor.
5. Nameplate and measured voltage, each phase.
6. Nameplate and measured amperage, each phase.
7. Starter thermal-protection-element rating.

B. Motors Driven by Variable-Frequency Controllers: Test for proper operation at speeds varying from minimum to maximum. Test manual bypass for controller to prove proper operation. Record observations, including controller manufacturer, model and serial numbers, and nameplate data.

3.08 TEMPERATURE TESTING

A. During testing, adjusting, and balancing, report need for adjustment in temperature regulation within the automatic temperature-control system.

B. Measure outside-air, wet- and dry-bulb temperatures.

3.09 TEMPERATURE-CONTROL VERIFICATION

A. Verify controllers are calibrated and commissioned.

B. Check transmitter and controller locations and note conditions that would adversely affect control functions.

C. Record controller settings and note variances between set points and actual measurements.

D. Verify operation of limiting controllers (i.e., high- and low-temperature controllers).

E. Verify free travel and proper operation of control devices such as damper and valve operators.

F. Verify sequence of operation of control devices. Note air pressures and device positions and correlate with airflow and water-flow measurements. Note speed of response to input changes.

G. Confirm interaction of electrically operated switch transducers.

H. Confirm interaction of interlock and lockout systems.

I. Verify main control supply-air pressure and observe compressor and dryer operations.

J. Record voltages of power supply and controller output. Determine if the system operates on a grounded or nongrounded power supply.

K. Note operation of electric actuators using spring return for proper fail-safe operations.

3.10 TOLERANCES

A. Set HVAC system airflow and water flow rates within the following tolerances:
1. Supply, Return, and Exhaust Fans: Minus 5 to plus 5 percent.
2. Air Outlets and Inlets: Minus 5 to plus 5 percent.
3. Heating-Water Flow Rate: Minus 5 to plus 5 percent.
4. Cooling-Water Flow Rate: Minus 5 to plus 5 percent.

3.11 REPORTING

A. Comply with the requirements for IDAT as specified in 01400.

B. Contract Documents Examination Report: Based on examination of the Contract Documents as specified in "Examination" Article above, prepare a report on the adequacy of design for system balancing devices. Recommend changes and additions to system balancing devices to facilitate proper performance measuring and balancing. Recommend changes and additions to HVAC systems and general construction to allow access for performance measuring and balancing devices.
1. Submit this report with 60 days from the Contractor's notice to proceed.

C. Status Reports: As Work progresses, prepare reports to describe completed procedures, procedures in progress, and scheduled procedures. Include a list of deficiencies and problems found in systems being tested and balanced. Prepare a separate report for each system and each building floor for systems serving multiple floors.

3.12 FINAL REPORT

A. Comply with the requirements for IDAT as specified in 01400.

B. Report: Typewritten or computer printout in letter-quality font, on standard bond paper, in 3-ring binder, tabulated and divided into sections by tested and balanced systems. Provide a approved water and air balance report for inclusion in O & M materials required by 01770; "Closeout Procedures and Submittals."

C. Include a certification sheet in front of binder signed and sealed by certified testing and balancing engineer.
   1. Include a list of instruments used for procedures, along with proof of calibration.

D. Final Report Contents: In addition to certified field report data, include the following:
   1. Pump curves.
   2. Fan curves.
   3. Manufacturers' test data.
   4. Field test reports prepared by system and equipment installers.
   5. Other information relative to equipment performance, but do not include approved Shop Drawings and Product Data.

E. General Report Data: In addition to form titles and entries, include the following data in final report, as applicable:
   1. Title page.
   2. Name and address of testing, adjusting, and balancing Agent.
   3. Project name.
   4. Project location.
   5. Architect's name and address.
   6. Engineer's name and address.
   7. Contractor's name and address.
   8. Report date.
   9. Signature of testing, adjusting, and balancing Agent who certifies the report.
   10. Summary of contents, including the following:
      a. Design versus final performance.
      b. Notable characteristics of systems.
      c. Description of system operation sequence if it varies from the Contract Documents.
   11. Nomenclature sheets for each item of equipment.
   12. Data for terminal units, including manufacturer, type, size, and fittings.
   13. Notes to explain why certain final data in the body of reports vary from design values.
   14. Test conditions for fans and pump performance forms, including the following:
      a. Settings for outside-, return-, and exhaust-air dampers.
      b. Conditions of filters.
      c. Cooling coil, wet- and dry-bulb conditions.
      d. Face and bypass damper settings at coils.
      e. Fan drive settings, including settings and percentage of maximum pitch diameter.
      f. Settings for supply-air, static-pressure controller.
      g. Other system operating conditions that affect performance.

F. System Diagrams: Include schematic layouts of air and hydronic distribution systems. Present with single-line diagrams and include the following:

   1. Water flow rates.
   2. Pipe and valve sizes and locations.
   3. Terminal units.
   4. Balancing stations.

G. Heat-Exchanger/Converter Test Reports:

1. Unit Data: Include the following:
   a. Unit identification.
   b. Location.
   c. Service.
   d. Make and type.
   e. Model and serial numbers.
   f. Ratings.

2. Steam Test Data: Include design and actual values for the following:
   a. Inlet pressure in psig (kPa).
   b. Condensate flow rate in lb/h (kW).

3. Water Test Data: Include design and actual values for the following:
   a. Entering-water temperature in deg F (deg C).
   b. Leaving-water temperature in deg F (deg C).
   c. Entering-water pressure in feet of head or psig (kPa).
   d. Water pressure differential in deg F (deg C).
   e. Water flow rate in gpm (L/s).

H. Pump Test Reports: Calculate impeller size by plotting the shutoff head on pump curves.

1. Unit Data: Include the following:
   a. Unit identification.
   b. Location.
   c. Service.
   d. Make and size.
   e. Model and serial numbers.
   f. Water flow rate in gpm (L/s).
   g. Water pressure differential in feet of head or psig (kPa).
   h. Required net positive suction head in feet of head or psig (kPa).
   i. Pump rpm.
   j. Impeller diameter in inches (mm).
   k. Motor make and frame size.
   l. Motor horsepower and rpm.
   m. Voltage at each connection.
   n. Amperage for each phase.
   o. Full-load amperage and service factor.
   p. Seal type.

2. Test Data: Include design and actual values for the following:
   a. Static head in feet of head or psig (kPa).
   b. Pump shutoff pressure in feet of head or psig (kPa).
   c. Actual impeller size in inches (mm).
   d. Full-open flow rate in gpm (L/s).
   e. Full-open pressure in feet of head or psig (kPa).

f. Final discharge pressure in feet of head or psig (kPa).
g. Final suction pressure in feet of head or psig (kPa).
h. Final total pressure in feet of head or psig (kPa).
i. Final water flow rate in gpm (L/s).
j. Voltage at each connection.
k. Amperage for each phase.

I. Instrument Calibration Reports: Include the following data:

1. Instrument type and make.
2. Serial number.
3. Application.
4. Dates of use.
5. Dates of calibration.

3.13 ADDITIONAL TESTS

A. Within 90 days of completing testing, adjusting, and balancing, perform additional testing and balancing to verify that balanced conditions are being maintained throughout and to correct unusual conditions.

END OF SECTION 15950